



US010468937B2

(12) **United States Patent**
Pearce, Jr. et al.

(10) **Patent No.:** **US 10,468,937 B2**
(45) **Date of Patent:** **Nov. 5, 2019**

(54) **CANTILEVER STATOR**

(71) Applicant: **Tesla Motors, Inc.**, Palo Alto, CA (US)

(72) Inventors: **Edwin M. Pearce, Jr.**, San Francisco, CA (US); **Jim Robbins**, San Francisco, CA (US); **Scott Heines**, Sunnyvale, CA (US); **David F. Nelson**, Menlo Park, CA (US); **Gary A. Pinkley**, Lino Lakes, MN (US); **Michael Balsamo**, San Francisco, CA (US); **Augusto E. Barton**, Palo Alto, CA (US)

(73) Assignee: **TESLA, INC.**, Palo Alto

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 768 days.

(21) Appl. No.: **14/557,224**

(22) Filed: **Dec. 1, 2014**

(65) **Prior Publication Data**

US 2016/0156245 A1 Jun. 2, 2016

(51) **Int. Cl.**
H02K 5/00 (2006.01)
H02K 5/15 (2006.01)

(52) **U.S. Cl.**
CPC **H02K 5/15** (2013.01); **H02K 5/00** (2013.01)

(58) **Field of Classification Search**
CPC .. H02K 5/00; H02K 5/15; H02K 5/12; H02K 5/20; B60L 11/1803; B60L 11/1805; B60K 2001/006; B60K 2006/4816
USPC 310/216.118, 402, 405-407, 411, 425, 310/429, 85, 87-89, 418, 432
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,531,668 A	9/1970	Cathey	
3,577,024 A	5/1971	Inagaki et al.	
4,516,044 A	5/1985	Bone	
4,796,352 A *	1/1989	Kawada	H02K 5/00 29/596
5,220,233 A	6/1993	Birch et al.	
6,191,511 B1	2/2001	Zysset	
6,329,731 B1	12/2001	Arbanas et al.	
6,359,355 B1 *	3/2002	Hartsfield	H02K 1/148 310/254.1

(Continued)

FOREIGN PATENT DOCUMENTS

CN	1993872 A	7/2007
CN	103138520 A	6/2013

(Continued)

OTHER PUBLICATIONS

Collins English Dictionary, Definition of Hole, 12th Edition 2014.*

(Continued)

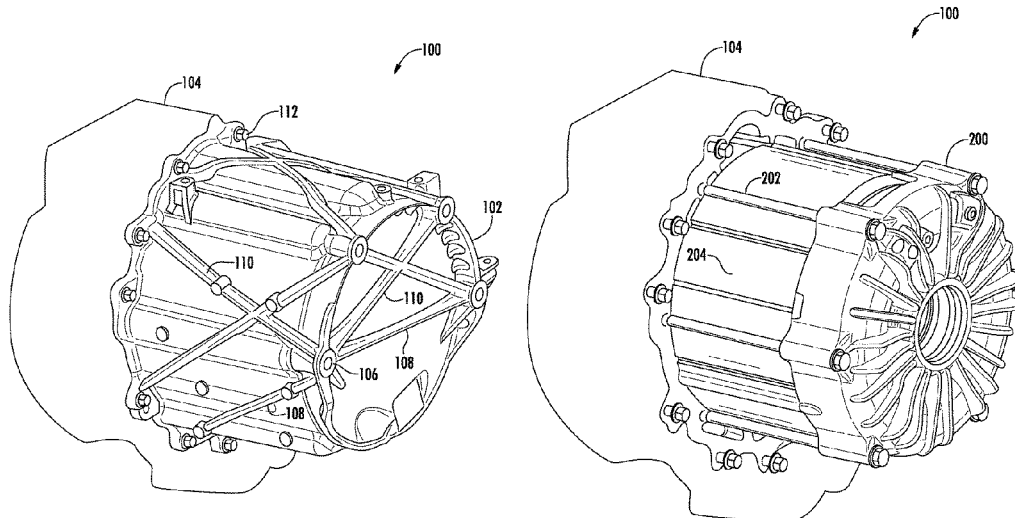
Primary Examiner — Quyen P Leung
Assistant Examiner — Eric Johnson

(74) *Attorney, Agent, or Firm* — Garlick & Markison;
Bruce E. Garlick

(57) **ABSTRACT**

An electric motor includes: a housing having a first rotor bearing and a stator support surface; a cantilever stator that includes a lamination stack, a first side of the lamination stack abutting the stator support surface and a second side of the lamination stack abutting a stator endbell that has a second rotor bearing, wherein the cantilever stator is held by way of tie rods attaching the stator endbell to the housing; and a rotor in the cantilever stator, the rotor held by the first and second rotor bearings.

19 Claims, 7 Drawing Sheets



(56)

References Cited

U.S. PATENT DOCUMENTS

6,680,552 B2* 1/2004 Linden H02K 5/20
123/41.31
7,156,195 B2 1/2007 Yamagishi et al.
8,183,723 B2 5/2012 Fee et al.
8,400,029 B2 3/2013 Sugimoto et al.
8,427,018 B2 4/2013 Dutau et al.
8,427,019 B2 4/2013 Garriga et al.
8,432,076 B2 4/2013 Garriga et al.
2003/0137200 A1* 7/2003 Linden H02K 5/20
310/59
2003/0200761 A1* 10/2003 Funahashi F01C 21/10
62/228.4
2005/0268464 A1 12/2005 Burjes et al.
2006/0255666 A1* 11/2006 Williams H02K 5/24
310/51
2008/0030087 A1* 2/2008 De Filippis F04D 25/082
310/58
2008/0116838 A1* 5/2008 Hattori B60H 1/3223
318/722
2008/0272661 A1 11/2008 Zhou et al.
2009/0121563 A1 5/2009 Zhou et al.
2012/0153718 A1 6/2012 Rawlinson et al.
2013/0136633 A1* 5/2013 Kanda F04D 13/06
417/410.1

2013/0187517 A1* 7/2013 Asao H02K 1/185
310/68 D
2014/0021831 A1* 1/2014 Hayashi H02K 5/22
310/432
2014/0271280 A1* 9/2014 Ley F04D 13/024
417/420
2015/0084478 A1* 3/2015 Yamashita H02K 5/04
310/216.114

FOREIGN PATENT DOCUMENTS

JP 55061255 A 5/1980
JP 05078156 U 10/1993
JP 2008228486 A 9/2008
JP 2008245352 A 10/2008
JP 2012080733 A* 4/2012
JP 2013115860 A 6/2013
JP 2013153580 A 8/2013
JP 2015152946 A 8/2015

OTHER PUBLICATIONS

Yagi et al., Machine Translation of JP2012080733, Apr. 2012 (Year: 2012).*

* cited by examiner

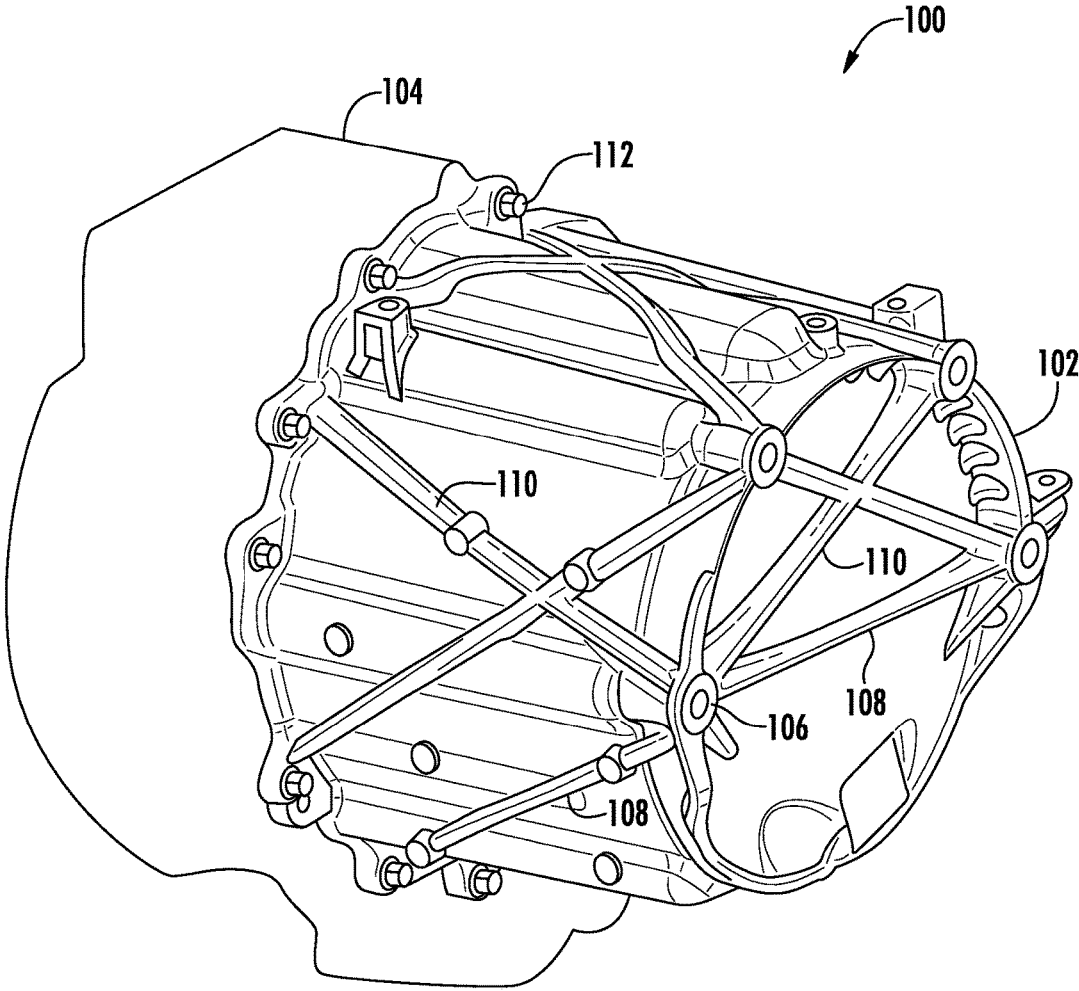


FIG. 1

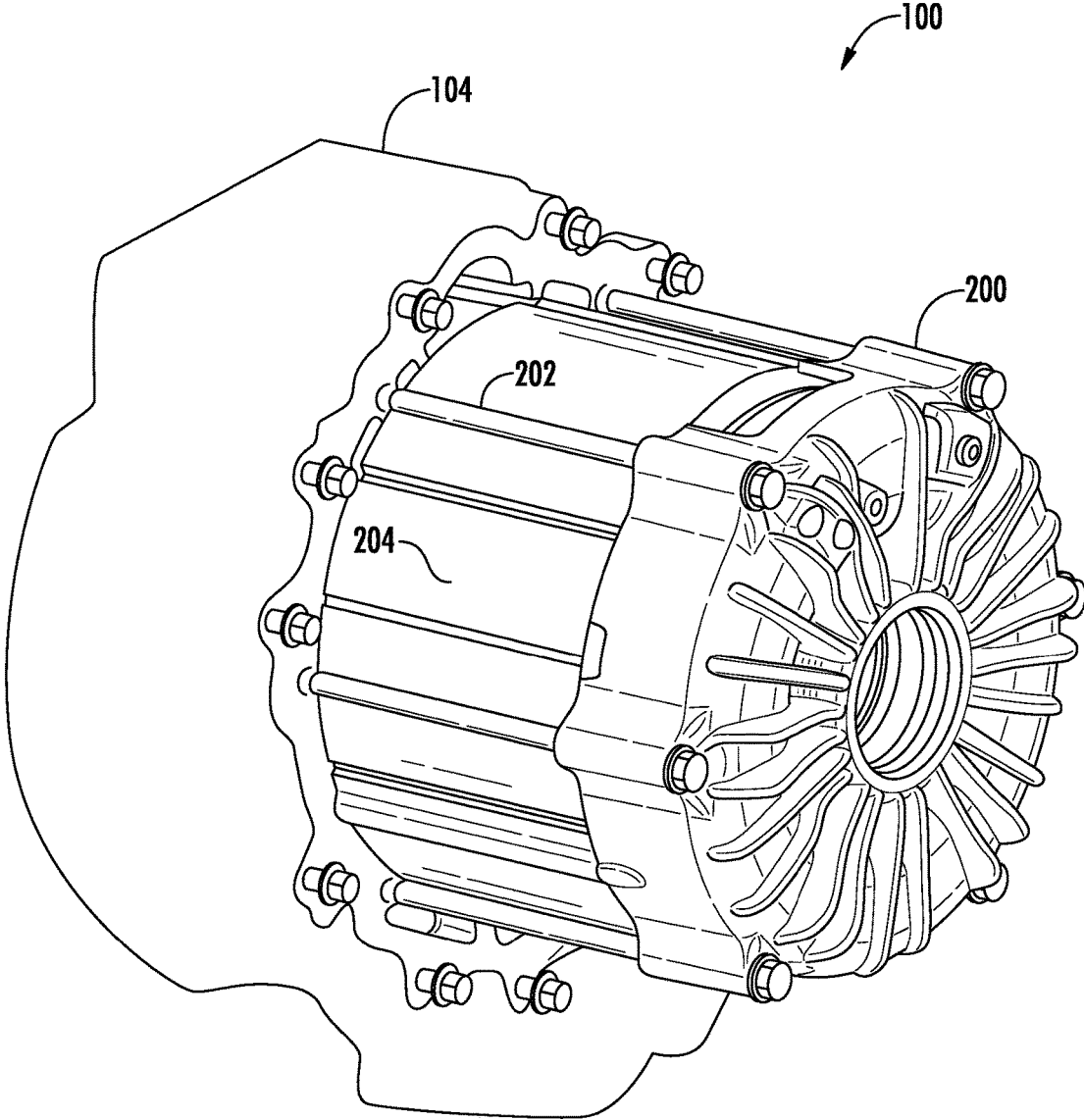


FIG. 2

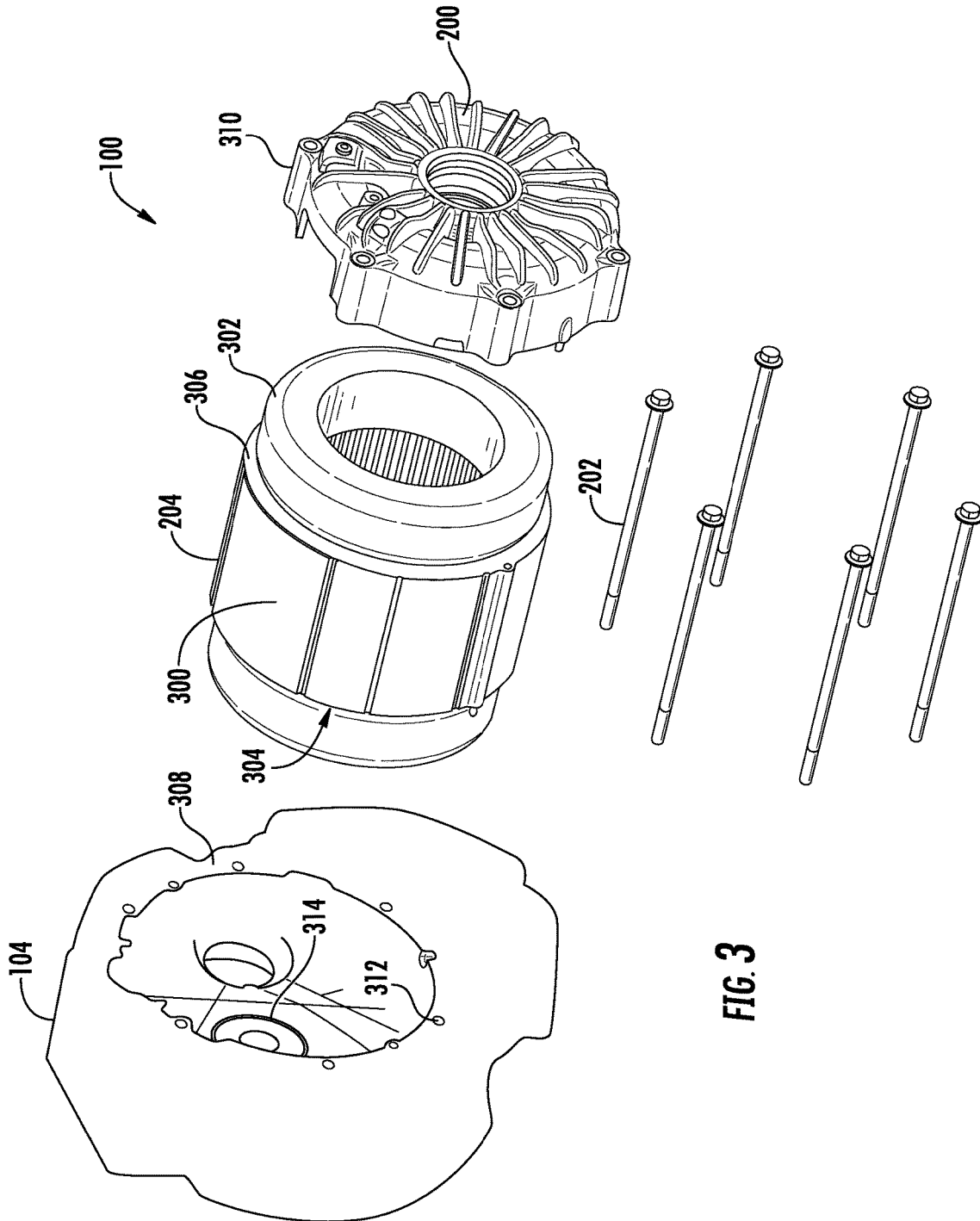


FIG. 3

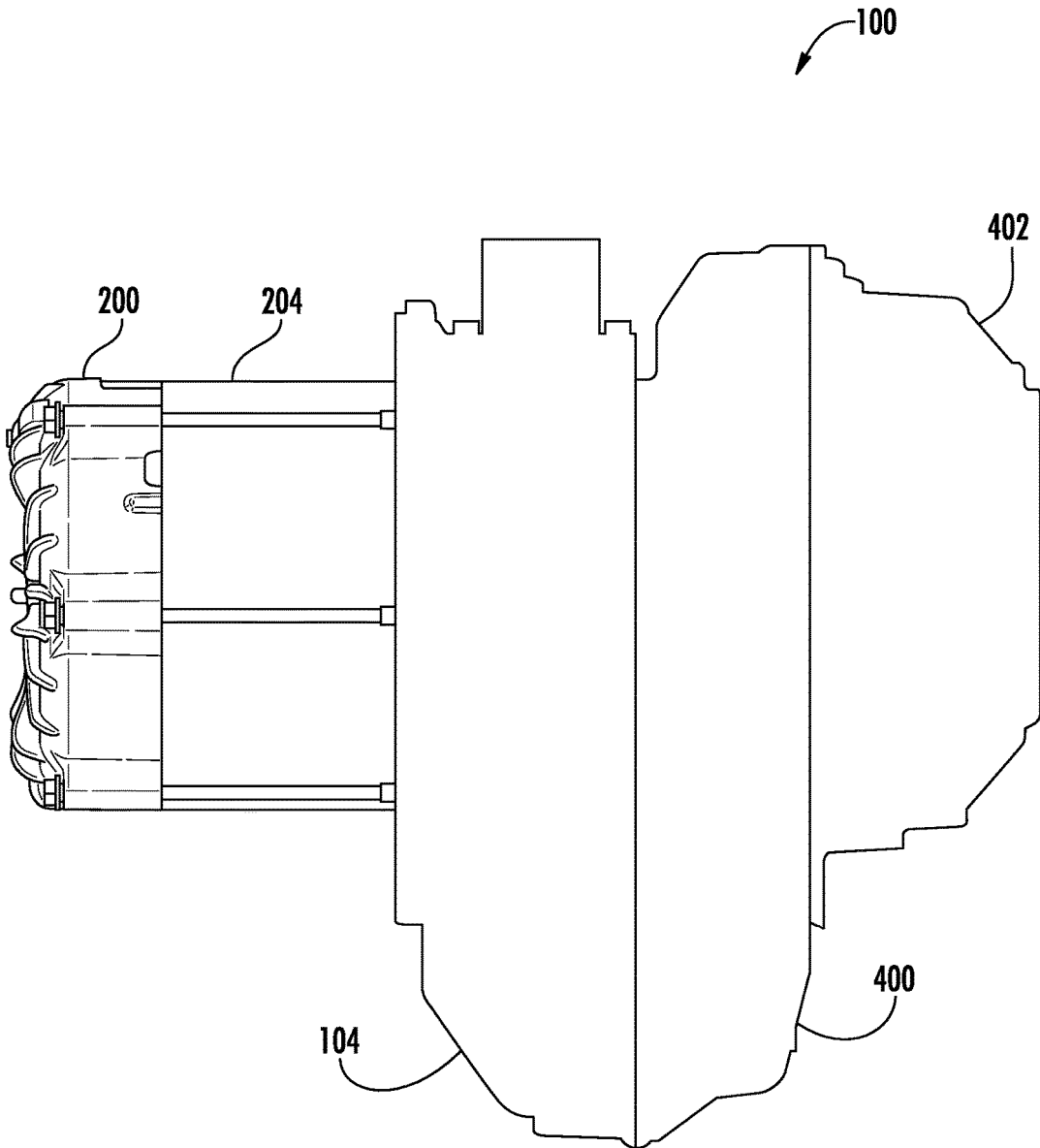


FIG. 4

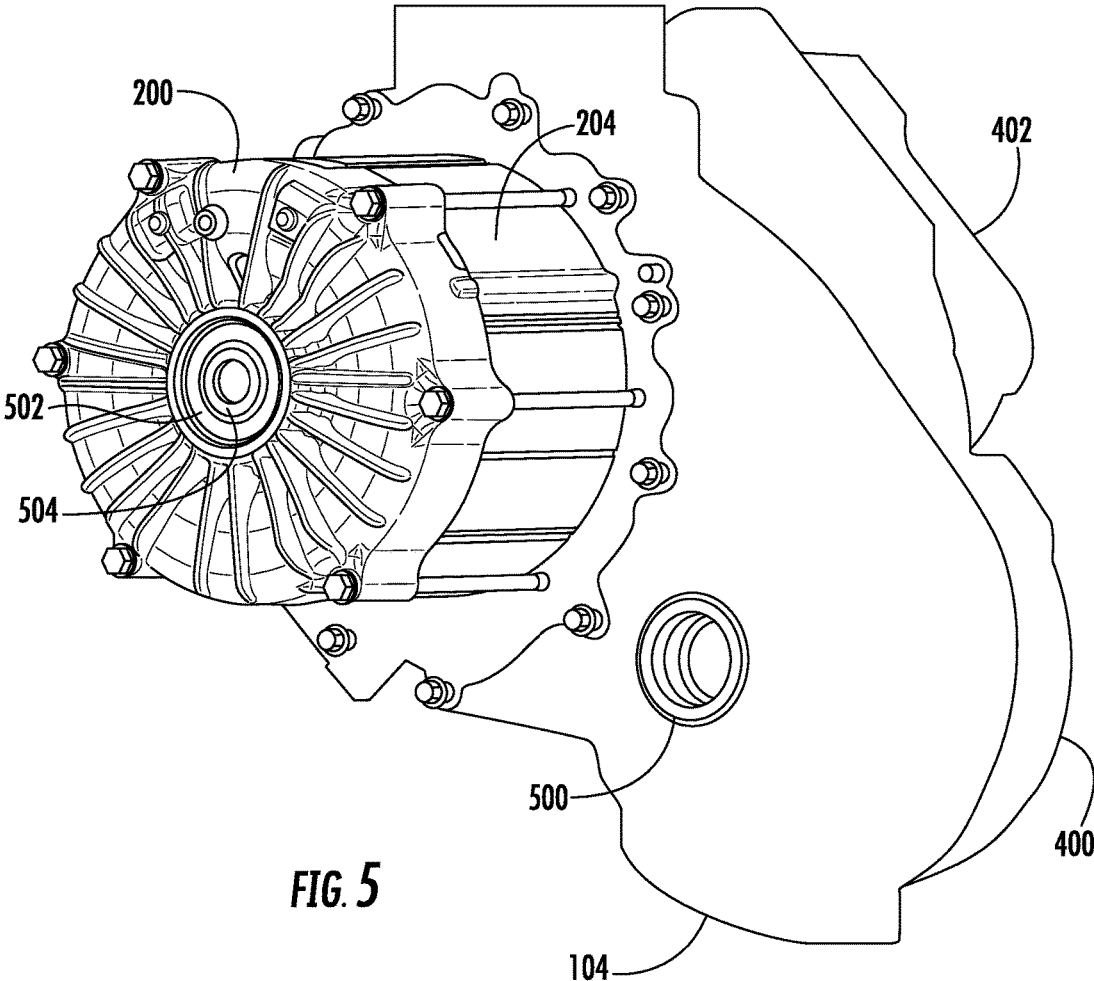


FIG. 5

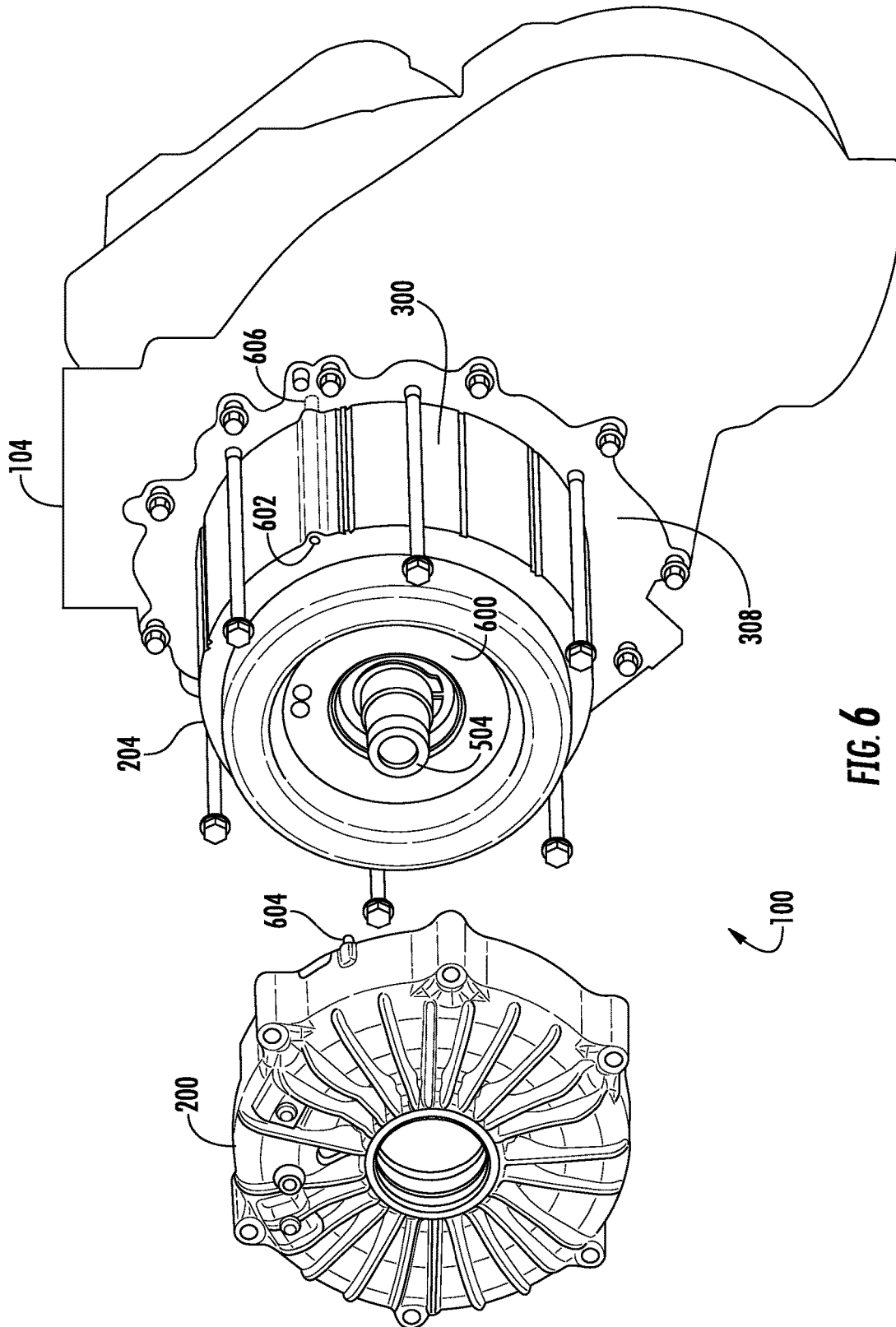


FIG. 6

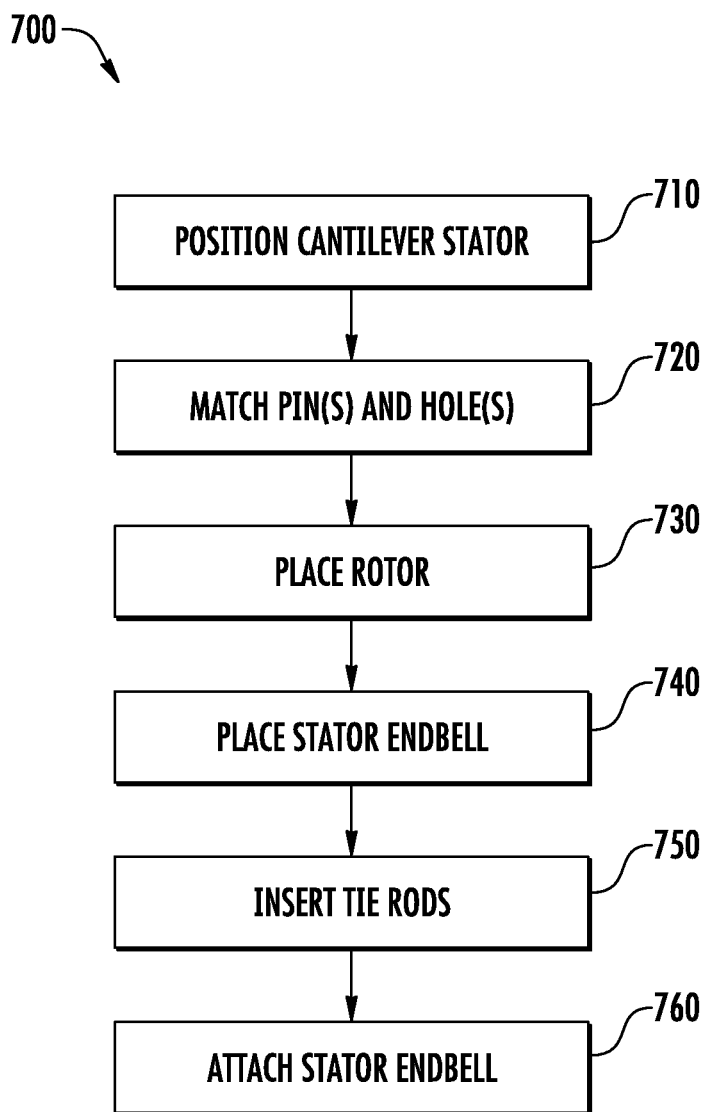


FIG. 7

1

CANTILEVER STATOR

BACKGROUND

Electric motors and other electrical drive units are used in a variety of contexts. For example, some vehicles have one or more electric motors used for propelling the vehicle. Such motor(s) can be the vehicle's sole traction mode, as in a pure electric vehicle, or it/they can be used in combination with another traction mode, such as in a hybrid vehicle. In some vehicles, separate electric motors are used for driving respective front and rear axles.

The electric motor has a rotor and a stator, where the stator can be contained in part of a housing that also encloses a gearbox and in some cases other components. The process of manufacturing such motors can include a stage of closely fitting together a stator and a housing component, such as a cast aluminum part. In order to assemble the stator into its proper location inside the housing, it may be necessary to heat the cast housing so that its dimensions increase, and thereafter relatively quickly insert the stator component. Thereafter, the contraction as the housing cools down creates the close fit between the parts.

SUMMARY

In a first aspect, an electric motor includes: a housing having a first rotor bearing and a stator support surface; a cantilever stator that includes a lamination stack, a first side of the lamination stack abutting the stator support surface and a second side of the lamination stack abutting a stator endbell that has a second rotor bearing, wherein the cantilever stator is held by way of tie rods attaching the stator endbell to the housing; and a rotor in the cantilever stator, the rotor held by the first and second rotor bearings.

Implementations can include any or all of the following features. The cantilever stator is positioned by at least one pin, a first end of the pin extending into one of the first and second sides of the lamination stack, and a second end of the pin extending into a corresponding one of the stator support surface and the stator endbell. The first end of the pin extends into a hole that is stamped into at least an outer lamination of the lamination stack. The cantilever stator is positioned by multiple pins at each of the first and second sides of the lamination stack. The tie rods are positioned evenly around a circumference of the stator endbell. The tie rods pass through openings in the stator endbell, extend along an outer surface of the cantilever stator, and are attached to the housing at the stator support surface. The housing and the stator endbell are cast pieces. The electric motor further comprises a bucket that covers the stator endbell, tie rods and cantilever stator, the bucket attached to the housing. The electric further comprises reinforcement struts on the bucket. The bucket is essentially cylindrical, and wherein the reinforcement struts comprise at least a first pair of crossing reinforcement struts on a bottom or a side surface of the bucket. The reinforcement struts further comprise at least a second pair of crossing reinforcement struts on another of the bottom or the side surface of the bucket. The bucket is configured to react torque generated by the electric motor.

In a second aspect, an electric motor includes: a housing having a stator support surface; a cantilever stator; means for holding the cantilever stator onto the stator support surface; and a rotor in the cantilever stator.

In a third aspect, a method of assembling an electric motor includes: positioning a cantilever stator and a housing rela-

2

tive each other so that a first side of a lamination stack of the cantilever stator abuts a stator support surface on the housing; placing a rotor within the cantilever stator so that the rotor is held by at least a first rotor bearing in the housing; placing a stator endbell against a second side of the lamination stack, the rotor being held by at least a second rotor bearing on the stator endbell; and attaching the stator endbell to the housing using tie rods, thereby holding the cantilever stator.

Implementations can include any or all of the following features. The method further comprises positioning the cantilever stator relative to the housing using at least one pin. Attaching the stator endbell to the housing comprises passing the tie rods through openings in the stator endbell so that the tie rods extend along an outer surface of the cantilever stator, and attaching the tie rods to the housing at the stator support surface.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 shows an example of an electric motor with a cantilever stator having a bucket cover.

FIG. 2 shows an example of the electric motor of FIG. 1 without the bucket cover.

FIG. 3 shows a partially exploded view of the electric motor in FIG. 2.

FIG. 4 is a side view of the electric motor in FIG. 2.

FIG. 5 is a perspective view of the electric motor in FIG. 4.

FIG. 6 shows an example of the electric motor in FIG. 5 with the stator endbell removed.

FIG. 7 is an example of a method of assembling an electric motor.

DETAILED DESCRIPTION

This document describes examples of electric motors configured to have a cantilever stator attached to a housing by way of tie bonds. Such designs can facilitate a convenient manufacturing process in which the assembly of the housing and stator components is simplified, while allows for adjustments or reassembly of parts if necessary.

FIG. 1 shows an example of an electric motor **100** with a cantilever stator having a bucket cover **102**. The cantilever stator is underneath the bucket cover in this illustration, and the motor further has a housing **104** that includes various components that are not explicitly shown for simplicity. In some implementations, a gearbox, a power inverter, electric contactors, a cooling system and motor control circuitry are located on the inside or the outside of the housing, as applicable.

The bucket cover **102** can serve one or more purposes for the motor. In some implementations, the cover isolates or otherwise shields a cooling system on or near the stator. For example, the cooling system circulates coolant (e.g., oil or air) around the stator, and the cover can then help direct the coolant onto the stator surface and collect liquid running off the stator. In some implementations, the cover reacts torque generated by the electric motor. For example, the bucket cover has one or more attachments **106** for securing the end of the bucket to a frame or other vehicle component, and torque is then reacted through the cover back into the housing **104**.

The bucket cover **102** can have one or more reinforcement struts **108**. One or more struts can be placed on the outside or inside of the cover, or both. The strut can be created as part of manufacturing the bucket (e.g., in a molding or

casting process), or can be attached afterwards (e.g., by welding). The cover and the strut can be made from any sufficiently strong material, such as metal (e.g., aluminum). In some implementations, one or more crossing reinforcement struts **110** are used. The cover can have crossing reinforcement struts on a bottom or a side surface thereof, or both.

The bucket cover **102** is attached to the housing **104** by any suitable technique. In some implementations, matching attachments are provided near those edges of these respective components that abut when the cover is attached. For example, one or more bolts **112** can be used.

FIG. 2 shows an example of the electric motor **100** of FIG. 1 without the bucket cover. That is, the motor is now seen to have a stator endbell **200** attached to the housing **104** by way of multiple tie rods **202**, thereby holding a cantilever stator **204** in position relative to the housing. That is, the stator endbell and the tie rod attachment to the housing provide a structural reinforcement that secures the stator to the housing.

The stator endbell and the housing can be manufactured using suitable techniques. In some implementations either or both of these components are cast from aluminum or another metal. For example, the cast component can then be machined to provide certain features therein. The stator itself can be manufactured in any suitable way, such as by stamping multiple laminates into a desirable shape and then stacking the laminates so as to form a stator body. The individual laminations are not shown in this illustration for simplicity.

FIG. 3 shows a partially exploded view of the electric motor **100** in FIG. 2. That is, the housing **104**, the stator **204**, the stator endbell **200** and the tie rods **202** (in this case, six rods) are shown separated from each other. Here, the stator has a lamination stack **300** with stator endturns **302** at either end thereof. Particularly, the lamination stack forms a first side surface **304** (here obscured) that faces the housing **104**, and a second side surface **306** that faces the stator endbell **200**.

In assembly, the first side surface **304** will be brought to abut a stator support surface **308** on the housing **104**. Here, the surface **308** is planar and has a generally circular shape corresponding to the stator. The opening defined by the surface **308** is large enough to allow the endturns **302** on that side of the stator to extend somewhat into the interior of the housing (i.e., past the surface **308**).

Similarly, the second side surface **306** will be brought to abut the stator endbell **200** in assembly. Accordingly, the edge of the stator endbell can likewise be planar and have a generally circular shape corresponding to the stator, albeit its overall shape can differ from that of the surface **308**. The stator endbell has a hollow interior facing the stator, thereby allowing the endturns **302** on that side of the stator to extend somewhat into the endbell. That is, the tie rods can in a sense serve to clamp the stator **204** using the endbell, thereby holding the stator onto the stator support surface.

In this example, the attachments for the tie rods **202** are positioned evenly around a circumference of the stator endbell **200**, and likewise at the part of the housing **104** abutting the stator. In some implementations, the stator endbell has openings **310** formed thereon that correspond to the individual tie rod. For example, each of the tie rods can be passed through a corresponding one of the openings so that the tie rod extends along an outer surface of the stator (e.g., the lamination stack **300**). In some implementations, the end of the tie rod is attached at the housing. Any suitable technique for attaching can be used, including, but not

limited to, using threads in openings **312** on the surface **308**. The tie rods are made of a material having sufficient strength (e.g., steel).

The housing **104** is here shown having a bearing **314** in its interior. The bearing is positioned to hold one end of a rotor shaft (not shown) when the motor is assembled. The other end of the rotor shaft will be held by a corresponding (though not necessarily identical) bearing in the stator endbell **200**, for example as will be discussed below. That is, a rotor (not shown) carried by the rotor shaft will thereby be held in position within the stator **204** by way of the rotor bearings at each end of the shaft.

FIG. 4 is a side view of the electric motor **100** in FIG. 2. The motor is here shown as having the stator **204** held against the housing **104** by way of the stator endbell **200**, the housing further having another case **400** attached thereto. For example, the housing **104** and the case **400** together form an interior space in which the gearbox of the motor is located. A power electronics module **402** (e.g., an inverter) is here mounted to the case **400**. For example, the module **402** serves to convert DC into AC for driving the electric motor.

FIG. 5 is a perspective view of the electric motor **100** in FIG. 4. This illustration shows the motor having the stator endbell **200** and the stator **204**, the housing **104** and the case **400**, and the power electronics module **402**. The housing **104** and/or the case **400** can be configured for having one or more wheel shafts attached thereto. In some implementations, a half shaft (not shown) is connected to the gearbox through an opening **500** in the housing. Similarly, the case **400** can provide a corresponding opening on the other side for a corresponding half shaft. For example, a differential can be provided in the middle of two such half shafts, each shaft driving one wheel of one of the vehicle's axles.

Also, the stator endbell **200** is shown with a rotor bearing **502** that holds a rotor shaft **504**. That is, the bearing held by the endbell here provides one side of the rotational suspension of the shaft for the rotor.

FIG. 6 shows an example of the electric motor **100** in FIG. 5 with the stator endbell **200** removed. That is, the rotor shaft **504** is here seen to have a rotor **600** mounted thereon within the stator **204**. Also shown is a hole **602** formed in the lamination stack **300**. The hole **602** is here used with a pin **604** on the endbell; a corresponding pin **606** (shown in phantom) interacts with a respective hole in the stator support surface. The holes and the pins are used for positioning and orientating relative to each other the stator **204**, the stator endbell and the housing **104**. For example, the pin **604** can first be partially inserted into a corresponding opening in the endbell, such that the extending pin portion is then inserted into the opening **602** upon assembly. Similarly, the pin **606** can first be partially inserted into a corresponding opening on the other side of the lamination stack, such that upon assembly the extending pin portion is then inserted into an opening in the stator support surface **308**. In some implementations, the motor has more than one of the holes **602** on the circumference of the stator, with corresponding pins that create alignment between the stator and each of the endbell and the housing. For example, two or more holes can be placed at equal intervals around the stator.

The holes and the pins can be manufactured using any suitable technique. In some implementations, the hole **602** is stamped into the laminate as it is being manufactured. For example, all laminates can have the hole stamped into them in the same position on the circumference, thus creating a channel when the laminates are arranged in a stack (this

5

example is shown in the figure). As another example, only one or more of the outermost laminates in the stack can have the hole stamped into it/them. The pins can be made from any material of sufficient strength, such as steel.

FIG. 7 is an example of a method 700 of assembling an electric motor. The method can be performed in any of a variety of contexts, such as in the original manufacturing of the motor or in a subsequent repair or rebuild of an existing motor. Some examples described above (FIGS. 1-6) will be used for illustration, but the method can be performed also with other types of electric motors. Steps can be performed manually (i.e., by a person) or robotically, or in a combination thereof. The steps can be performed in a different order unless otherwise stated or indicated.

At 710, a cantilever stator is positioned. For example, the cantilever stator 204 and the housing 104 can be brought into position relative each other so that the first side surface 304 of the lamination stack of the cantilever stator is close to the stator support surface 308.

At 720, one or more pins and one or more holes are matched to each other. For example, the pin 606 extending from the stator can be inserted into the hole at the stator support surface 308.

At 730, a rotor is placed. For example, the rotor 600 can be placed within the cantilever stator 204 so that the rotor is held by the rotor bearing 314 in the housing 104.

At 740, a stator endbell is placed. In some implementations, the stator endbell 200 can be placed against the second side surface 306 of the lamination stack. For example, the rotor can then be held also by the rotor bearing 502 on the stator endbell. In some implementations, one or more pin-hole pairs are matched as part of placing the stator endbell.

At 750, one or more tie rods are inserted. For example, the tie rods 202 can be inserted through the openings 310.

At 760, the stator endbell is attached. In some implementations, the tie rods 202 are attached at the openings 312 of the stator support surface 308, thereby holding the cantilever stator in place. For example, a threaded attachment can be used.

Fewer or more steps can be performed in some implementations.

A number of implementations have been described as examples. Nevertheless, other implementations are covered by the following claims.

What is claimed is:

1. An electric motor for a vehicle comprising:

a housing having a first rotor bearing and a stator support surface;

a cantilever stator that includes a lamination stack, a first side of the lamination stack abutting the stator support surface and a second side of the lamination stack abutting a stator endbell that has a second rotor bearing, wherein the cantilever stator is held by way of tie rods attaching the stator endbell to the housing;

a rotor in the cantilever stator, the rotor held by the first and second rotor bearings; wherein the tie rods pass through openings in the stator endbell, extend along an outer surface of the cantilever stator, and are attached to the housing at the stator support surface; and

a bucket cover that covers the cantilever stator and the stator endbell, the bucket cover including:

a plurality of first attachments that attach a first end of the bucket cover to the housing;

a plurality of second attachments on a second end of the bucket cover for securing the second end of the bucket cover to the vehicle; and

6

a plurality of reinforcement struts extending from the plurality of second attachments to the first end of the bucket cover.

2. The electric motor of claim 1, wherein the cantilever stator is positioned by at least one pin, a first end of the pin extending into one of the first and second sides of the lamination stack, and a second end of the pin extending into a corresponding one of the stator support surface and the stator endbell.

3. The electric motor of claim 2, wherein the first end of the pin extends into a hole that is stamped into at least an outer lamination of the lamination stack.

4. The electric motor of claim 2, wherein the cantilever stator is positioned by multiple pins at each of the first and second sides of the lamination stack.

5. The electric motor of claim 1, wherein the tie rods are positioned evenly around a circumference of the stator endbell.

6. The electric motor of claim 1, wherein the housing and the stator endbell are cast pieces.

7. The electric motor of claim 1, wherein the bucket cover is essentially cylindrical, and the reinforcement struts are on a side surface of the bucket cover.

8. The electric motor of claim 7, wherein the reinforcement struts comprise at least a first pair of crossing reinforcement struts.

9. The electric motor of claim 8, wherein the bucket cover further comprises additional reinforcement struts on a bottom surface of the bucket cover, wherein the additional reinforcement struts comprise at least a second pair of crossing reinforcement struts.

10. The electric motor of claim 1, wherein the bucket cover is configured to react torque generated by the electric motor from the plurality of second attachments through the bucket cover and back to the housing.

11. A method of assembling an electric motor, the method comprising:

positioning a cantilever stator and a housing relative each other so that a first side of a lamination stack of the cantilever stator abuts a stator support surface on the housing;

placing a rotor within the cantilever stator so that the rotor is held by at least a first rotor bearing in the housing;

placing a stator endbell against a second side of the lamination stack,

the rotor being held by at least a second rotor bearing on the stator endbell;

attaching the stator endbell to the housing using tie rods, thereby holding the cantilever stator;

wherein attaching the stator endbell to the housing comprises passing the tie rods through openings in the stator endbell so that the tie rods extend along an outer surface of the cantilever stator, and attaching the tie rods to the housing at the stator support surface; and

placing a bucket cover over the cantilever stator and the stator endbell;

attaching a first end of the bucket cover to the housing using a plurality of first attachments; and

attaching a second end of the bucket cover to a vehicle using a plurality of second attachments of the bucket cover, wherein the bucket cover includes a plurality of reinforcement struts extending from the plurality of second attachments to the first end of the bucket cover.

12. The method of claim 11, further comprising positioning the cantilever stator relative to the housing using at least one pin.

13. The method of claim 11, further comprising:
connecting a case to the housing wherein a space formed
by the housing and the case is configured to house a
gearbox.

14. The electric motor method of claim 11, wherein the
bucket cover is configured to shield a coolant circulated
around the stator.

15. The method of claim 11, wherein the bucket cover is
configured to react torque generated by the electric motor
from the plurality of second attachments through the bucket
cover and back to the housing.

16. An electric motor for a vehicle comprising:
a housing having a first rotor bearing and a stator support
surface;

a cantilever stator that includes a lamination stack, a first
side of the lamination stack abutting the stator support
surface and a second side of the lamination stack
abutting a stator endbell that has a second rotor bearing,
wherein the cantilever stator is held by way of tie rods
attaching the stator endbell to the housing;

a rotor in the cantilever stator, the rotor held by the first
and second rotor bearings; and a bucket cover that
covers the cantilever stator and the stator endbell, the
bucket cover including:

a plurality of first attachments that attach a first end of the
bucket cover to the housing, a plurality of second
attachments for securing a second end of the bucket
cover to the vehicle; and

a plurality of reinforcement struts extending from the
plurality of second attachments to the first end of the
bucket cover.

17. The electric motor of claim 16, further comprising:
a case coupled to the housing to form a space configured
to house a gearbox.

18. The electric motor of claim 17, further comprising a
power electronics module coupled to the case.

19. The electric motor of claim 16, wherein the bucket
cover is configured to react torque generated by the electric
motor from the plurality of second attachments through the
bucket cover and back to the housing.

* * * * *